

Characterization of the $\text{La}_{1-x}\text{Sr}_x\text{Cr}_y\text{Fe}_{1-y}\text{O}_3$ ($x = 2,4,6,8$; $y = 2,5,8$) system

Kevin Kerstetter, Larry Pederson, Matt Chou, Greg Coffey,
Jeff Stevenson

ABSTRACT

Recently, lanthanum chromite and lanthanum ferrite based perovskite oxides have been extensively studied as a candidate for the interconnect and the cathode materials used in solid oxide fuel cells. Compositions of $\text{A}'_{1-x}\text{A}''_x\text{B}'_{1-y}\text{B}''_y\text{O}_{3-\delta}$, where $\text{A}' = \text{La, Y, and Sm}$, $\text{A}'' = \text{Mg, Ca, Sr, and Ba}$, $\text{B}' = \text{Co, Mn, and Cr}$, $\text{B}'' = \text{Fe and Al}$, have been reported. In certain cases these materials exhibit high conductivity properties but are limited by their dimensional stability in reducing environments. Sr-substituted $\text{LaCo}_{0.2}\text{Fe}_{0.8}\text{O}_3$ perovskite has shown high ionic-electronic conductivity and is considered as potential candidates for the cathode in solid oxide fuel cells (SOFC) as well as the electrolyte for oxygen separation membranes. The material, however, suffered poor dimensional stability in reducing environments. For this study the system $\text{La}_{1-x}\text{Sr}_x\text{Cr}_y\text{Fe}_{1-y}\text{O}_3$ ($x = 2,4,6,8$; $y = 2,5,8$) was selected, effectively replacing the cobalt in the previously mentioned system with chromium due to chromium having better dimensional stability in reducing environments than cobalt.

The phase development of the system was studied in order to determine which of the 12 compositions were single phase perovskites and what sintering temperatures were necessary to achieve gas tight density. Phase characterization was determined by x-ray diffraction analysis (XRD). The single phase compositions were compared by evaluating their electronic and mechanical properties. The electronic properties were evaluated using oxygen ion conductivity and four-point dc measurements as a function of temperature. Linear thermal expansion was also investigated along with thermogravimetric analysis (TGA) and differential thermal analysis (DTA). The TGA testing was also done using a low oxygen environment to determine if the weight loss could be made irreversible. The mechanical properties were evaluated by measuring their elastic properties, biaxial flexure strength, microhardness, and indentation fracture toughness. In addition, microstructure characterization and fractography were also used to further characterize the properties of the material.

The sintering study indicated that the compositions with relatively large amounts of strontium and chromium would not yield single phase, dense samples. XRD results indicated that the second phase present in these

compositions was SrCrO_4 . Electrical and ionic conductivities were less than that of similar systems using a cobalt substitution as opposed to the chromium B site substitution used here. TGA results had data that correlated to the ionic conductivity of the system, in that the compositions with high strontium had the highest ionic conductivity and the highest reversible weight loss. TGA experiments done in nitrogen indicated that the weight loss was irreversible in a low oxygen environment, implying the weight loss was due to a loss of lattice oxygen. The dilatometry indicated that the compositions with the largest amounts of strontium had the highest TEC values, with slope changes between the temperatures of 300°C and 1000°C. DTA testing to determine the nature of these slope changes was inconclusive.

The mechanical testing generally showed a trend of decreasing values as the strontium level increased. The elastic modulus appeared to decrease with increasing Sr content. Young’s modulus of 128 to 192 GPa and shear modulus of 51 to 74 GPa were measured. A biaxial flexure strength of 243 MPa was measured for lowest Sr content batches. Batches with higher Sr concentrations ($x = 0.6$ to 0.8) showed extensive cracking. Indentation toughness showed a decrease with increasing Sr content. In addition, fractography was used to characterize the critical flaw and the fracture mode.